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The Effectiveness of Incorporating a Real-Time Oculometer System in a Commercial Flight Training Program

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This research could not have been conducted without the cooperation of the Instructor Pilots (IPs) and the trainees. At a time when the role of the airline pilot is undergoing immense scrutiny, the willingness of the IPs and trainees to participate in this research is demonstrable of their professionalism and devotion to the improvement of their job.

We would like to acknowledge the work of the NASA technicians who were responsible for transporting the oculometer system to Winston Salem, N.C., installing the system (usually between midnight and 7 a.m.), and maintaining the system during data collection.

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THE EFFECTIVENESS OF INCORPORATING A REAL-TIME OCULOMETER SYSTEM IN A COMMERCIAL FLIGHT TRAINING PROGRAM

By

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Raymond H. Kirby[3]

INTRODUCTION

One frequently cited example of an information processing system involving a man-machine interface is the piloting task. Only recently, however, have technological advances allowed researchers to gain insight into the information gathering processes by pilots and copilots. Since Merchant (1969) developed the Honeywell oculometer, an unobtrusive, wide-angle, eye movement recording device, researchers for NASA/Langley Research Center have evaluated various aspects of instrument scanning behavior by private and commercial pilots (e.g., Dick, 1980; Harris and Christhilf, 1980; Spady, 1978; Spady and Harris, 1981).

Recently, investigators evaluated the effectiveness of providing information from prior research on the training of commercial airline pilots and copilots (Jones, Coates and Kirby, 1983). Jones et al., sought to determine if information concerning the instrument scanning behavior of experienced pilots benefited pilot and copilot trainees in a commercial flight training program. The results indicated that a training tape, developed by NASA/LaRC, had little or no effect on instructor pilots' (IPs) ratings of trainees' simulator performance or trainees' self-reported eye-scan behavior. The IPs and trainees suggested that a program providing individually-oriented feedback of each trainee's scanning behavior would be more helpful than a general type of intervention strategy.

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The major purpose of the present study, therefore, was to assess the effectiveness of incorporating a real-time oculometer system in a commercial flight training program on performance, and self-reported scanning behavior, by pilot and copilot trainees.

The flight training personnel had suggested previously (see Jones, et al., 1983) that an unusually large number of pilot and copilot trainees showed a performance decrement on or about the third day of simulator training. The research by Jones et al., (1983) failed to find objective support for a performance decrement; however, feedback from pilot and copilot trainees indicated that performance difficulties might be related to the order in which their simulator training occurred. Trainees received simulator training in pairs requiring the trainees to alternate the order of training within a session. Since these data were not available in the previous study, the present research sought to incorporate objective means of investigating the "third day phenomenon," including the role of order of training on performance.

METHOD

Flight Training Program

The flight training program attended by each trainee involved four weeks of training, consisting of 15 days of ground school and five days of 737 flight simulator training. Simulator training was received by the trainees in pilot or copilot pairs, each pair having the same IP for all five simulator sessions. The daily simulator sessions lasted four hours for each pair of trainees. Over the five sessions, each pair of trainees alternated the order in which they would receive two hours of instruction. Although each pair of trainees performed virtually the same flight maneuvers in each simulator session, the order in which they were asked to perform the maneuvers differed somewhat. The time of day at which each simulator session occurred was rotated among the pairs of trainees throughout the five days. The first session of each day began typically at 0800, with subsequent sessions beginning every four hours after that until all trainees had received training. Generally, the training sessions concluded by midnight each day.

In most cases, the subjects received training on five consecutive days; however, some pilot trainees in the control and experimental groups had a two day break between simulator Sessions 2 and 3.

<u>NASA/Langley Research Center Oculometer System</u>

The oculometer system developed by Merchant (1969) and adapted for use in experiments involving the piloting task by NASA engineers has been explained elsewhere (e.g., Harris and Christhif, 1980). The system used a corneal reflection technique that allowed for a cubic foot of head movement. As can be seen in Figure 1, an electro-optic head, through which an invisible infrared light was emitted, was installed in the lower inside instrument panel. The oculometer computer processed the reflection from the cornea, through the electro-optic head and generated a small white dot that would vary in congruence with the eye movements of the trainee.

For purposes of the present project, two systems were developed to provide IPs and trainees feedback concerning instrument scan behavior. The real-time system (RTS) combined the computer generated eye-movement indicator (i.e., the small white dot) with sophisticated video equipment to provide the IPs with a real-time view of the scanning behavior of each trainee. It should be noted that only the trainee undergoing a training period (i.e., two hours) was tracked. No attempt was made to track instrument scanning by the non-flying trainee.

Figure 2 shows two video cameras installed on the ceiling of the simulator and a small video receiver in a compartment to the right of the IPs' console. The camera's picture of the flying trainees instrument panel was shown through the video receiver with the small white dot superimposed over it. The computer generated dot would move around the instrument panel picture simulating the eye-movements of the trainees as they performed the various flight maneuvers. The RTS allowed the IP to evaluate and suggest adjustments in the instrument scans of the trainees.

The videotape feedback system (VFS) was developed to provide trainees with videotapes of their scanning behavior following each simulator session.

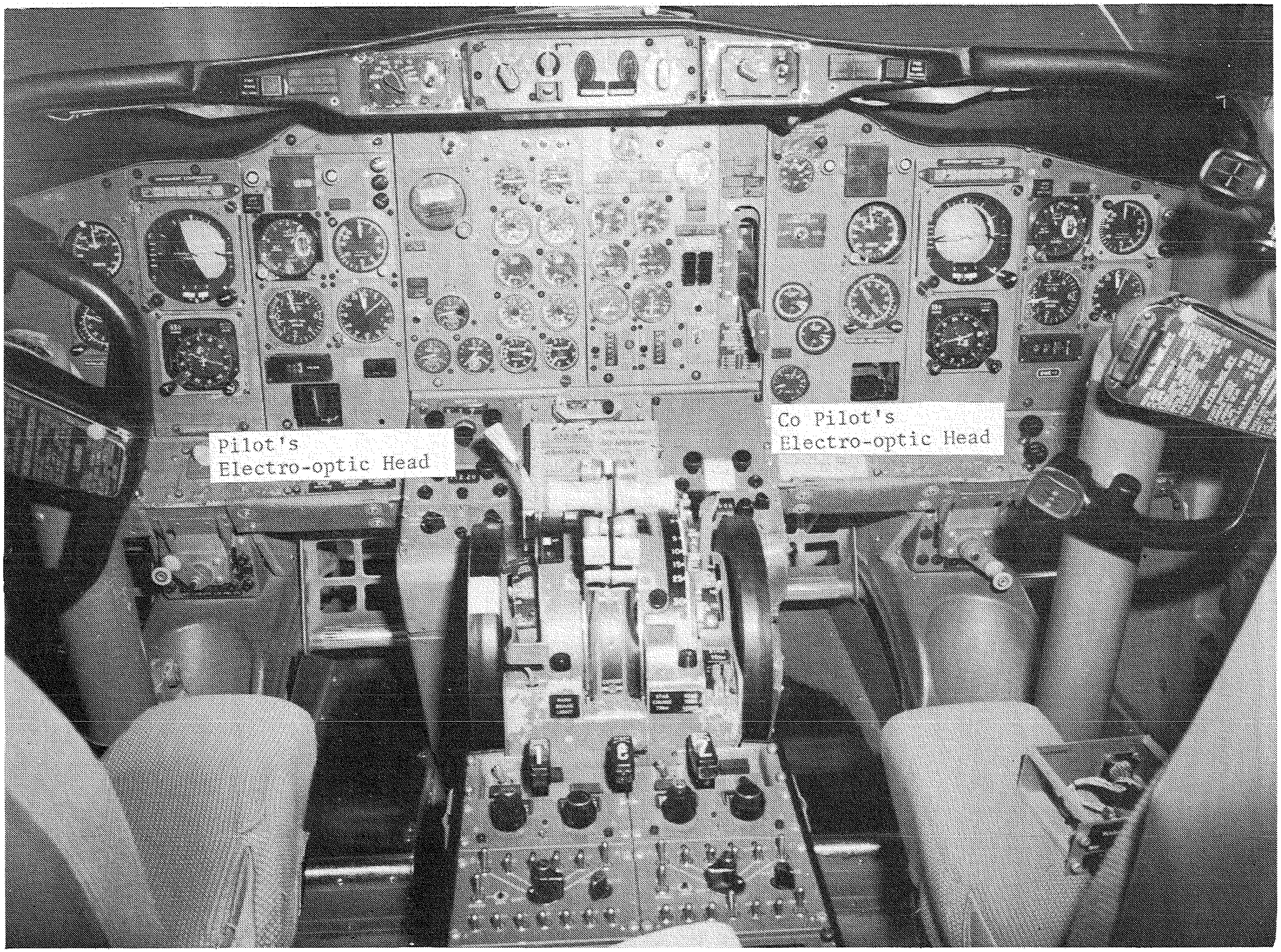

Figure 1. Flight instrument panel.

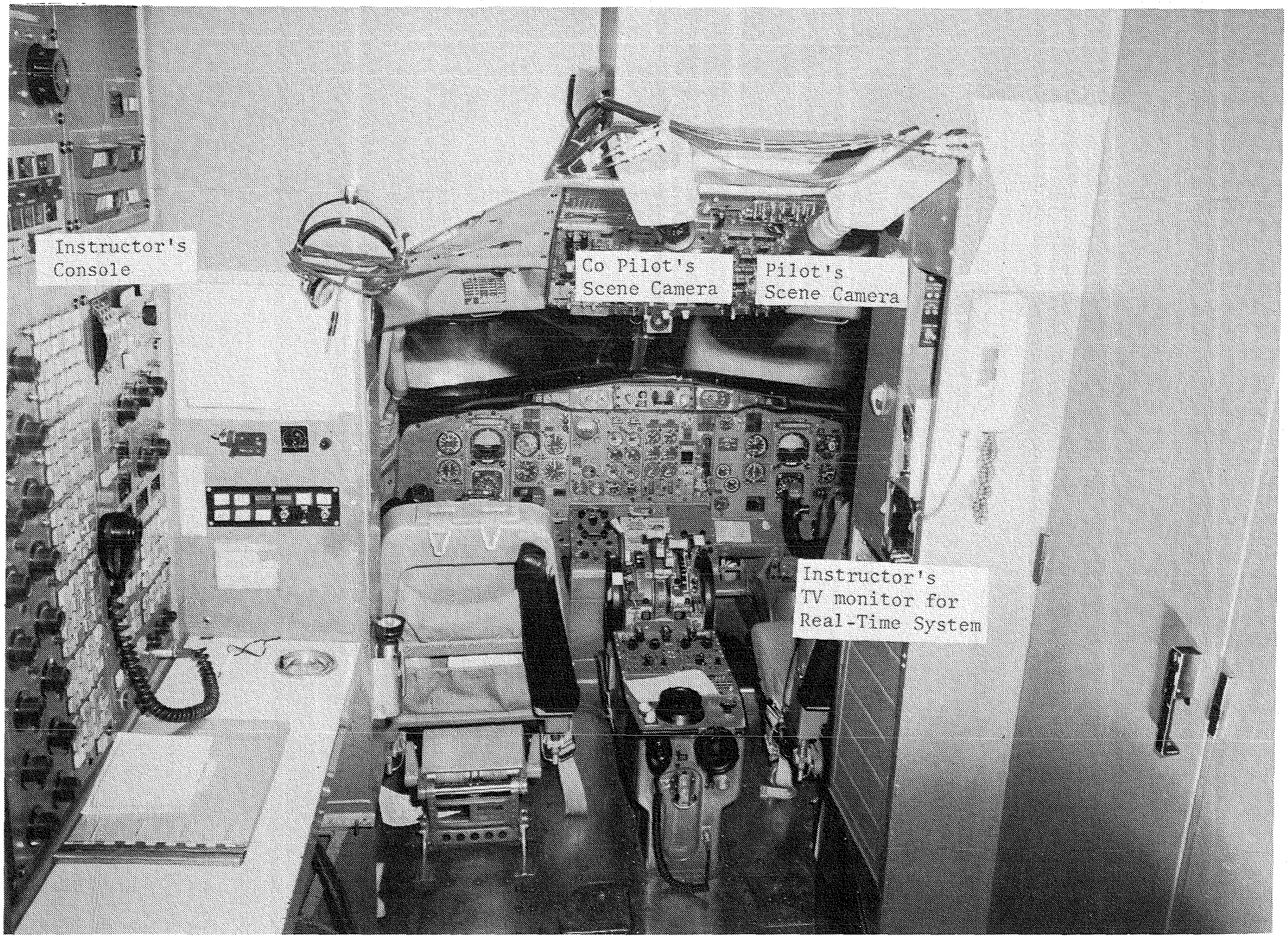

Figure 2. General interior view of simulator.

Each videotape was accompanied with a procedure to view specific maneuvers, if desired. The VFS allowed IPs to provide in-depth feedback to trainees about their instrument scanning, and also permitted trainees to review interesting or problematic maneuvers.

Subjects

The subjects were 58 pilot and copilot trainees attending the 737 flight training program at Piedmont Airlines Training Center. Of the 28 trainees in the control group, data from seven trainees were eliminated from the experiment for being incomplete. Of the 30 trainees in the experimental group, data from six trainees were eliminated since their training occurred during the calibration of the oculometer systems; two trainees declined to participate, and data from six trainees were eliminated for being incomplete. Table 1 presents the relevant demographic data on the remaining trainees.

Table 1. Demographic data for copilots in the control group (CC), pilots in the control group (CP), copilots in the experimental group (XC), and pilots in the experimental group (XP).

		Flight Experience (In Average Hours)			
Group	N	Small Aircraft	Non-Jet	Jet	737
CC	10	1676.0	1150.0	1090.0	0
CP	11	2500.0	4290.9	1164.7	1577.6
XC	4	980.0	2337.5	1287.0	0
XP	12	2212.0	1962.0	891.7	1660.7

An additional group of subjects consisted of nine IPs. All IPs were fully qualified pilots on the Boeing 737 and had been IPs for at least one year.

Instructor Rating Forms

The instructor rating forms used in this study were a revised version of the forms used in the previous study (Jones, et al., 1983). The

researchers met with the IPs prior to the start of the present study and revised the rating forms specifically for each simulator session. IPs were asked to rate each trainees' performance on various tasks in each simulator session using a magnitude estimation scale of 0-100 (D'Amato, 1970), with a higher score reflecting better performance. These data were used to compare IPs' ratings of performance for trainees exposed to feedback of their scanning behavior to those trainees in the control group.

The IPs for the trainees in the experimental groups were also asked to rate the usefulness of the RFS on a scale of 1-10, where 1 corresponded to "not useful at all," and 10 corresponded to "extremely useful." These data were used to assess the usefulness of the oculometer system for the experimental groups.

Eye-Scan Survey

The eye scan survey was a paper and pencil task which presented five different manual approach situations and diagrams of an instrument panel (see situations 1-5, Attachment I, Jones et al., 1983). The trainee was asked to draw the "typical" instrument scan pattern for each flight situation for a 10-second period. The order of presenting the flight situations was random to control for order effects. These data were used to measure changes in self-reported eye-scan patterns for control and experimental groups.

Trainee Rating Forms

Trainees in both control and experimental groups were asked to rate their performance for each simulator session using the same magnitude estimation scale (0-100) used by the IPs. These data were used to compare trainees' self-ratings of performance for control and experimental groups.

Subsequent to session five, trainees in the experimental groups were also asked to rate the usefulness of the oculometer system on a scale of 1-10, where 1 corresponded to "not useful at all" and 10 corresponded to "extremely useful." The data were used to assess the usefulness of the oculometer system as perceived by trainees in the experimental groups.

Procedure

Data were collected over a six month period, and involved three phases: (1) the control data collection phase; (2) the oculometer system calibration phase; and (3) the experimental data collection phase. Each phase is explained below.

Control Data Collection Phase.--A researcher met with each pair of trainees and their IP prior to the first day of simulator training. The trainees were shown the instructor rating forms and the trainee daily self-evaluation forms, and the data collection procedure was explained. The trainees completed an eye-scan survey following the first simulator session.

Subsequent to Session 5 of simulator training, trainees completed a second eye-scan survey, and were briefed as to the exact nature of the research, including (1) the goals of the research; (2) the "third-day phenomenon;" and (3) a request for suggestions for the use of the oculometer system as a training aid.

Oculometer System Calibration Phase.--The installation of the oculometer system, video-equipment and computer hardware was largely completed during the control data collection phase while the simulator was not being used. Since all the systems including the computer software required calibration, the researchers collected data on six trainees for one week, but decided *a priori* that these data would not be used in any analyses.

Experimental Data-Collection Phase.--The same procedure was used in collecting data with the experimental trainees as was used during the control data collection, with the exception that the IPs and trainees were briefed thoroughly concerning the RTS and VFS.

RESULTS AND DISCUSSION

During flight simulator training, pilot and copilot trainees must learn to gather various types of information from the aircraft instruments. The present research sought to determine whether trainees, receiving immediate

feedback from IPs and an opportunity to view videotapes of their scanning behavior, would (1) perform better than trainees in the control group; (2) rate the oculometer as being useful in the flight training program; and (3) show differences in self-reported scanning behavior from trainees in the control group.

Performance Ratings

As indicated above, the IPs and trainees used a magnitude estimation scale to rate performance, thus the raw scores could not be used to make comparisons between trainees. Therefore, difference scores were computed by transforming raw performance data into a matrix detailing performance relative to Session 1. It should be noted that various transformations of the data were attempted, including T-scores, and Session X minus the mean of Sessions 1 through 5; however, the present analysis, Session X minus Session 1, was found to best control for individual differences caused by using the magnitude estimation scale. Table 2 shows the average difference scores from IP ratings for each group in each simulator session.

Table 2. Average difference scores from IP ratings in simulator sessions 2-5 (Session 1 = baseline). CC = control copilots; CP = control pilots; XC = experimental copilots; XP = experimental pilots.

			Sessions			
Group	N		2	3	4	5
CC	10	Mean	5.46	8.27	9.74	14.98
		S.D.	9.12	6.00	12.07	9.43
CP	11	Mean	4.44	4.14	5.09	8.23
		S.D.	3.98	5.15	4.58	5.00
XC	4	Mean	-0.44	2.99	6.67	10.11
		S.D.	2.28	3.18	5.08	5.98
XP	12	Mean	4.88*	9.63	7.83	11.43
		S.D.	7.53	6.05	10.31	9.17

*N = 11

The data indicate that while each group generally showed improvement as they progressed through simulator training, there was no difference between the pilot control, copilot control and their respective experimental groups, given the similarity of their means and the magnitude of their variances.

Table 3 shows the average difference scores from trainees' self-ratings for each group in each simulator session. The trainees' self-ratings were similar to the IPs' ratings in that the trainees rated themselves as improving in each simulator session; however, the data indicate no difference between copilot controls, pilot controls, and their respective experimental groups.

These findings are supported by data from IPs and trainees ratings for control and experimental groups (i.e., collapsing across pilot and copilot groups). As can be seen in Table 4, neither the trainees' self-ratings nor the IPs' ratings indicated any difference in performance by control and experimental groups.

Table 3. Average difference scores from trainees self ratings in simulator Sessions 2-5 (Session = 1 baseline). CC = control copilot; CP = control pilots; XC = experimental copilots; XP = experimental pilots.

			Sessions			
Group	N		2	3	4	5
CC	10	Mean	3.50	8.70	14.30	17.40
		S.D.	12.03	18.29	16.98	19.38
CP	11	Mean	0.64	3.00	1.09	8.27
		S.D.	8.91	8.43	11.45	21.14
XC	4	Mean	1.50	4.00	7.50	10.00
		S.D.	4.73	1.16	2.89	7.07
XP	12	Mean	4.30*	7.50	8.17	14.55**
		S.D.	18.03	10.56	13.56	11.72

*N = 11
**N = 10

Table 4. Average difference scores from IPs' ratings and trainees' self-ratings in simulator Sessions 2-5 (Session 1 = baseline).

Rater	Group	N		Sessions 2	3	4	5
Trainees	Control	21	Mean	2.00	5.71	7.38	12.62
			S.D.	10.34	13.95	15.52	20.35
Trainees	Experimental	16	Mean	3.50*	6.63	8.00	13.33**
			S.D.	15.53	9.19	11.69	10.64
IPs	Control	21	Mean	4.93	6.11	7.30	11.45
			S.D.	6.75	5.80	9.04	8.03
IPs	Experimental	16	Mean	3.36*	7.97	7.54	11.06
			S.D.	6.84	6.14	9.13	8.25

*N = 14
**N = 15

IP Usefulness Ratings

Subsequent to each simulator session IPs were asked to rate the usefulness of the oculometer system on a scale of 1-10. Table 5 presents the results of these ratings.

Table 5. IPs' median usefulness ratings of the oculometer system in each of the simulator sessions (Scale = 1-10, where 1 corresponded to "system not useful and 10 corresponded to "system extremely useful"). XC = experimental copilots; XP = experimental pilots.

Group	N	Sessions 1	2	3	4	5
XC	4	3.00	3.50	3.25	4.00	4.25
XP	12	5.50*	5.00	5.25	5.50	4.50

*N = 11

These ratings seem to indicate that the IPs found the usefulness of the oculometer system to be of low to medium usefulness for both groups in each of the five simulator sessions. While the IPs rated the usefulness of the oculometer system slightly higher for pilot trainees, this may be a function of the higher number of pilot trainees than copilot trainees.

Trainees Ratings of Oculometer System

Subsequent to Session 5, each trainee was asked to rate the usefulness of the oculometer system and to indicate the number of times they used the VFS during their flight training. Table 6 presents the results of their ratings and their use of the video tape feedback system.

Table 6. Trainees' final evaluation of the usefulness of the oculometer system (Scale = 1-10, where 1 corresponded to "system not useful" and 10 corresponded to "system extremely useful"), and the average number of times the trainees used the video tape feedback system (VFS) during flight simulator training.

Group	N	Mean	Usefulness	Number of Times VFS System was Used
XC	4	Mean	6.75	1.75
		S.D.	2.63	1.50
XP	8	Mean	6.25	2.87
		S.D.	1.50	1.93

The data indicate that (1) the trainees rated the oculometer system as being moderately useful, and (2) both pilot and copilot trainees used the VFS approximately twice during flight simulator training. The pilot trainees seemed to use the VFS more often than copilot trainees; however, once again, this may be a function of the larger number of pilot trainees undergoing training while the oculometer system was installed.

IP and Trainee Feedback

Throughout the course of this research, various types of feedback was solicited from IPs and trainees in both control and experimental groups. During the control data collection phase the IPs and trainees were asked whether there were any particular maneuvers where information concerning the trainees instrument scanning behavior would have been helpful. The IPs' and trainees' comments in the control groups can be seen in Attachments I and II, respectively.

During the experimental data collection phase, five types of feedback were solicited from the IPs and trainees. Each is described briefly below:

(1) Following each simulator session, IPs were asked whether they used the RTS to provide feedback to the trainee and, if so to please explain. (see Attachment III).

(2) Following each simulator session, trainees were asked if they used the VFS and whether they found the information useful. (see Attachment IV).

(3) Trainees who had chosen to view video tapes of their instrument scan behavior were asked which maneuvers they had viewed and to comment on VFS. (see Attachment V).

(4) Subsequent to final simulator session, IPs and trainees were asked whether they had used the VFS, which maneuvers were most helped by the system, and to make comments about the system. (see Attachments VI and VII).

Taken together, the IPs' and trainees' feedback indicated that the oculometer system may best function as a training device for trainees who may be having general difficulties with their instrument scanning, or specific difficulties. For example, the IP for trainees 2101 and 2102 found that their scans were slow and that they failed to cross-check raw data. However, the IP reported that after reviewing the videotapes with the trainees, their scanning behavior improved 40-50 percent. (See Attachment III, p. 27). The comments by the IP for trainee 2201 (Attachment III) indicate how the RFS was used to provide feedback for specific performance difficulties (i.e. not incorporating the IVSI into scan).

The comments by the trainees (see Attachment VII, p. 33) support the suggestion that the RFS and VFS were helpful when the trainees were encountering scan related difficulties. The comments by trainee 2204 exemplified the types of comments made by the trainees who utilized feedback from the systems.

Eye Scan Survey

As in the previous study (Jones, et al., 1983), the eye-scan survey was developed in an attempt to obtain subjective reports of the scan patterns of experienced pilots (IPs), pilot/copilot trainees early in training, and pilot/copilot trainees at the completion of simulator training. The purpose of the eye-scan surveys was to describe how the trainees, at these various stages of training, would report their scanning of the aircraft instruments. Because of the developmental nature of the instrument, the reader is cautioned to view the following results as purely descriptive.

To summarize the data from the eye-scan survey, the responses of each trainee to the five flight situations were summarized as a transition matrix presenting the frequency with which the trainee shifted to instrument y at time, t+1, given that he/she was viewing instrument x, at time t. The resulting matrices for each group were pooled to provide descriptions of step-wise scan behaviors for those groups. The frequency matrices were converted to transition probablity matrices in which the entries represent the conditional probabilities that the trainees shifted to instrument y at time t+1 given that they were viewing instrument x at time t.

Table 7 presents the transitional probability matrices for each group (following Session 1) and the IPs. The matrices present, as rows, the instrument indicated at time t with the columns presenting the instruments indicated at time t+1 . For example, given that the instructors were viewing the airspeed (AS) indicator at time t, the probability that the next instrument indicated was the Flight Director (FD) was 0.533, while for the control copilots, the conditional probability was 0.863. The control pilots was 0.481, etc. It should be noted that the right most column presents the marginal probabilities associate with each of the instruments. For example, the IPs indicated that they spend 0.202 of the time viewing the AS indicator, while the CC trainees spend 0.155 of the time on the AS indicator etc.

Judging from the marginal probabilities each group, except the control pilot group, spent more time on the FD and less time on each of the other instruments than the IPs. In all cases, however, the transitional probabilities for each group of trainees do not appear to be radically different from those of the IPs.

Table 8 presents the transitional probability matrices for each group (following Session 5), and the IPs. As can be seen by the marginal probabilities the trainee groups continued to devote more time to the FD and less time to the other instruments than the IPs.

In the previous study, Jones et al., (1983) found that trainees shifted from having similar transitional probabilities to the IPs after Session 1 to being more dissimiliar after Session 5. The major point of divergence between the trainees and the IPs being an increased emphasis on the use of the FD by trainees. In the present study the trainees showed an higher

Table 7. Transition matrix for instructor pilots (IP), control-copilots (CC), control-pilots (CP), experimental copilots (XC), experimental pilots (XP), collapsed across situations and subjects. These data are from eye-scan survey following Session 1.*

TIME t		TIME t+1 AS	FD	ALT	ADF	HSI	VSI	Marginals
AS	IP	--	0.533	0.128	0.000	0.128	0.191	0.202
	CC	--	0.863	0.061	0.015	0.030	0.030	0.155
	CP	--	0.481	0.185	0.037	0.167	0.130	0.196
	XC	--	0.778	0.000	0.000	0.111	0.111	0.182
	XP	--	0.750	0.028	0.000	0.083	0.139	0.157
FD	IP	0.412	--	0.329	0.035	0.153	0.071	0.365
	CC	0.310	--	0.267	0.033	0.214	0.176	0.492
	CP	0.404	--	0.337	0.022	0.202	0.034	0.324
	XC	0.391	--	0.217	0.000	0.196	0.196	0.465
	XP	0.287	--	0.287	0.052	0.191	0.183	0.500
ALT	IP	0.175	0.425	--	0.000	0.100	0.300	0.172
	CC	0.088	0.789	--	0.000	0.070	0.053	0.133
	CP	0.115	0.365	--	0.096	0.038	0.385	0.189
	XC	0.133	0.400	--	0.000	0.067	0.400	0.152
	XP	0.157	0.533	--	0.000	0.100	0.200	0.130
ADF	IP	0.000	0.666	0.000	--	0.333	0.000	0.026
	CC	0.143	0.714	0.000	--	0.143	0.000	0.016
	CP	0.250	0.250	0.000	--	0.500	0.000	0.044
	XC	0.000	0.000	0.000	--	0.000	0.000	0.000
	XP	0.000	1.00	0.000	--	0.000	0.000	0.017
HSI	IP	0.160	0.160	0.200	0.120	--	0.360	0.107
	CC	0.043	0.848	0.022	0.000	--	0.087	0.108
	CP	0.394	0.091	0.212	0.030	--	0.273	0.120
	XC	0.000	0.700	0.300	0.000	--	0.000	0.101
	XP	0.136	0.818	0.000	0.000	--	0.045	0.096
VSI	IP	0.100	0.333	0.100	0.033	0.433	--	0.129
	CC	0.024	0.780	0.146	0.024	0.024	--	0.096
	CP	0.086	0.114	0.314	0.143	0.343	--	0.127
	XC	0.000	0.800	0.200	0.000	0.000	--	0.101
	XP	0.043	0.609	0.087	0.000	0.261	--	0.100

*Note:
AS = airspeed indicator
FD = flight director
ALT = altimeter
ADF = automatic director finder
HSI = horizontal speed indicator
VSI = vertical speed indicator

Group Size:
IP - 8
CC - 9
CP - 11
XC - 4
XP - 8
40

Table 8. Transition matrix for instructor pilots (IP), control copilots (CC), control-pilots (CP), experimental copilots (XC), experimental pilots (XP), collapsed across situations and subjects. These data (except for IPs) are from eye-scan survey following Session 5.*

TIME t		TIME t+1 AS	FD	ALT	ADF	HSI	VSI	Marginals
	IP	--	0.553	0.128	0.000	0.128	0.191	0.202
	CC	--	0.956	0.044	0.000	0.000	0.000	0.147
AS	CP	--	0.600	0.108	0.046	0.123	0.123	0.187
	XC	--	0.857	0.000	0.000	0.071	0.071	0.122
	XP	--	0.718	0.026	0.026	0.128	0.103	0.168
	IP	0.412	--	0.329	0.035	0.153	0.071	0.365
	CC	0.322	--	0.260	0.045	0.120	0.252	0.522
FD	CP	0.364	--	0.394	0.045	0.129	0.068	0.382
	XC	0.293	--	0.241	0.000	0.190	0.276	0.504
	XP	0.398	--	0.305	0.034	0.127	0.136	0.509
	IP	0.175	0.425	--	0.000	0.100	0.300	0.172
	CC	0.000	0.952	--	0.000	0.032	0.016	0.136
ALT	CP	0.083	0.367	--	0.017	0.117	0.417	0.173
	XC	0.000	0.643	--	0.000	0.000	0.357	0.122
	XP	0.000	0.727	--	0.000	0.121	0.152	0.142
	IP	0.000	0.666	0.000	--	0.333	0.000	0.026
	CC	0.000	0.900	0.000	--	0.000	0.100	0.022
ADF	CP	0.167	0.333	0.000	--	0.500	0.000	0.035
	XC	0.000	0.000	0.000	--	0.000	0.000	0.000
	XP	0.000	0.667	0.000	--	0.000	0.333	0.013
	IP	0.160	0.160	0.200	0.120	--	0.360	0.107
	CC	0.000	0.000	0.833	0.067	--	0.033	0.065
HSI	CP	0.351	0.351	0.297	0.081	--	0.189	0.107
	XC	0.200	0.700	0.000	0.000	--	0.100	0.087
	XP	0.150	0.632	0.053	0.053	--	0.158	0.082
	IP	0.100	0.333	0.100	0.333	0.433	--	0.129
	CC	0.000	0.922	0.078	0.000	0.000	--	0.109
VSI	CP	0.100	0.300	0.200	0.000	0.400	--	0.116
	XC	0.000	0.684	0.263	0.000	0.053	--	0.165
	XP	0.050	0.600	0.200	0.000	0.150	--	0.086

*Note:
AS = airspeed indicator
FD = flight director
ALT = altimeter
ADF = automatic director finder
HSI = horizontal speed indicator
VSI = vertical speed indicator

Group Size:
IP - 8
CC 9
CP - 11
XC - 4
XP - 8
40

reliance on the FD than the IPs following Session 1, with an even higher reliance after Session 5. However, the shift in the reliance on the FD by the trainees is so small it is doubtful that the differences are greater than what might occur by chance. Finally, there does not appear to have been any difference that distinguished the experimental trainees from the control trainees.

Conclusions

The performance data from the IPs and trainees indicated that the oculometer system did not have a uniform effect on performance by pilots and copilots in the experimental group. However, the reader is advised to use caution in evaluating the oculometer system based solely on this one study. It should be remembered that the measures used in this study were not objective and, therefore, were subject to various psychometric errors. Futhermore, it may be that the measures used were not sensitive enough to detect differences between control and experimental groups. These qualifications notwithstanding, the data do provide important information about how the oculometer was used and the type of impact it seemed to have during flight simulator training.

In contrast to the performance ratings, an evaluation of the usefulness ratings and feedback from the IPs and trainees suggested that the oculometer system was useful in ameliorating specific instrument scanning problems (e.g. fixating on a particular instrument; omitting an important instrument during a particular maneuver). While a large number of the trainees and IPs reported that they had benefitted significantly from information provided by the oculometer system, its impact did not appear to be of sufficient magnitude to produce differences in performance ratings between the experimental and control groups.

There are at least three possible explanations for the discrepancy between the performance ratings and the usefulness/feddback data. First, the trainees began the flight training program with a significant amount of flight experience, including general knowledge of information gathering procedures; therefore, the amount of instrument-scan feedback necessary for

improvement was relatively small. Second, flight simulator performance was multidimensional with instrument scanning behavior being only one of a number of dimensions used by the IPs and trainees to develop an overall rating of performance. For example, since "stick and rudder" skills were usually well developed, IPs may have emphasized knowledge of aircraft systems and emergency procedures more than instrument scanning behavior. Third, it should be noted that the performance measures used in this study were not objective, and, therefore, were subject to various psychometric errors. It may well be that the performance ratings were not sufficiently sensitive to detect differences between the control and experimental groups.

In conclusion, these data would appear to indicate that the major beneficial role of a real-time oculometer system in a commercial flight training program would be for problem solving or refinement of instrument scanning behavior, rather than a general instructional scheme. Although cost-effective measures were not incorporated in the present research, it seemed clear from the comments by flight training personnel that the oculometer system was valuable in eliminating expensive remedial training sessions for several trainees. It is suggested that this line of research be continued with the incorporation of objective data (e.g., state of the aircraft data), measures of cost effectiveness, and with trainees having less flight experience.

Third-Day Phenomenon

As indicated above the flight training personnel at Piedmont Airlines had suggested that an unusually large number of pilot and copilot trainees showed a performance decrement on or about the third day of simulator training. The present research following the suggestions by pilot and copilot trainees collected data concerning the role of order of training with performance decrements. Furthermore, the IPs and trainees had suggested that performance in a particular session is generally judged relative to the previous session rather than session one.

Results and Discussion.--Table 9 shows average IPs performance ratings for control and experimental groups as a function of the order of training. These data seem to support the suggestion that order of training within a

Table 9. Average difference scores (Session X - Session X-1) from IPs' ratings for control and experimental groups as a function of the order of training.

Group	Order In Session 1	N		Session/Order 2/2	3/1	4/2	5/1
Control	1	10	Mean	3.38	1.36	-0.05	5.23
			S.D.	5.10	4.01	6.02	7.18
Experimental	1	6	Mean	2.34	6.63	-1.20	4.56
			S.D.	8.22	4.16	7.16	3.20
				Session/Order 2/1	**3/2**	**4/1**	**5/2**
Control	2	5	Mean	4.58	2.79	0.99	3.09
			S.D.	0.90	2.60	1.94	1.03
Experimental	2	6	Mean	3.72	1.94	0.28	3.05
			S.D.	7.14	2.95	4.13	3.13

Table 10. Average difference scores (Session X - Session X-1) from trainees' self-ratings for control and experimental groups as a function of the order of training.

Group	Order In Session 1	N		Session/Order 2/2	3/1	4/2	5/1
Control	1	10	Mean	-0.50	2.80	-1.50	6.20
			S.D.	3.69	10.88	15.09	22.48
Experimental	1	6	Mean	0.67	8.00	-2.17	8.33
			S.D.	10.61	11.58	17.15	12.11
				Session/Order 2/1	**3/2**	**4/1**	**5/2**
Control	5	5	Mean	11.40	5.00	8.00	-2.40
			S.D.	13.22	6.67	10.34	16.32
Experimental	6	6	Mean	6.00	0.33	0.33	5.00
			S.D.	21.73	14.17	11.43	10.00

session may affect performance. Specifically, the data indicate that trainees who receive their training second in a simulator session show less improvement over performance in the previous session than if they had received their training first. By comparing the performance ratings of trainees who went first in any particular session with trainees who went second in that session, the trainees who went second typically showed less improvement in performance over the previous session than those who had undergone training first. It should also be noted that both control and experimental trainees who went second in Session 4, performed less well than in Session 3 (i.e., performance decrement). The data from the trainee self-ratings support these findings, as can be seen in Table 10.

The data from the trainees' self-ratings are directly supportive of the importance of order of training in performance. Once again, trainees who went second in a session tended to show less improvement over the previous session performance than trainees who went first. Futhermore the trainees who went second in Session 4 showed a performance decrement.

Conclusions.--These findings are interesting and suggest that order of training "within a session" has significant impact of performance ratings by IPs and the trainees' own judgement of their performance. The results indicated that trainees who performed second within a session received lower ratings from IPs' and self-ratings than trainees who performed first. Furthermore, the data revealed that trainees who performed second in the fourth simulator session showed a performance decrement (i.e. a rating lower than on the previous session), while trainees who performed first maintained a gradual rate of improvement.

Within each training session, the "flying pilot" performs a variety of precision and emergency maneuvers. In order to perform the maneuvers successfully, the trainee is assisted by the "non-flying pilot" who must be responsive to commands by the "flying pilot." In other words, while the "flying pilot" is largely responsible for the state of the aircraft, he/she is dependent upon the responsiveness of the "non-flying pilot." Feedback from the trainees in this study suggest that (1) the trainees performing second within a session were fatigued from having participated in the training of the trainee who went first, and (2) the trainees who performed first

were fatigued following their two hours of training and therefore were not as responsive as usual while performing the "non-flying pilot" tasks. Furthermore, the trainees attributed the performance decrement in session four to cumulative fatigue effects.

Of course the present findings can only be substantiated with further research; however, it is hoped that the flight training personnel will find these results informative and useful. Perhaps just the knowledge that order within a session can affect performance will alleviate some of the mystery surrounding the phenomenon, and promote future inquiry by IPs and the flight training personnel.

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ATTACHMENT I

IPs' Comments on Trainee Rating Forms (Control Group)

Q. During this simulator session, were there any particular maneuvers where information concerning the trainee's instrument scanning behavior would have been helpful? Please be specific.

IP	Trainee	Status	IP Data
102	1103	CP	Session 1 - It would have been helpful in almost the whole session Session 3 - V1 Cut
102	1104	CP	Session 1 - It would have been helpful in almost the whole session Session 3 - V1 Cut
103	1201	P	Session 1 - Steep turns and Emergency Descent
105	1204	P	Session 1 - Emergency Descent
107	1105	CP	Session 1 - No
102	1207	P	Session 2 - V1 Cut and Steep turns
102	1208	P	Session 1 - V1 Cut, Steep turns and smalls Session 2 - V1 Cut and Steep turns
107	1107	CP	Session 2 - Nearing minimums on VOR approach

ATTACHMENT II

Trainees' Comments on Self-Rating Form (Control Group)

Q. Were there any maneuvers during this training session where feedback concerning your instrument scanning behavior would have been helped.

IP	Trainee	Status	Trainee Comments
101	1101	CP	Session 1 - Fixating, not smooth X check on approaches. Session 5 - Scan check would be good during initial session. Toward end old ways are modified up to speed.
101	1102	CP	Session 1 - During ADF and ILS. Session 2 - Holding, entry and turns in holding. Session 3 - Instrument approaches and hold - course intercept and turns.
102	1103	CP	Session 1 - Steep turns. V1 Cut. Session 2 - Instrument scanning during review of APP and while setting NAV receivers. Session 4 - Instrument scan on V1 Cut or Eng fire immediately after take off. Session 5 - low Viz, CAT II APP. Scan.
102	1104	CP	Session 1 - More time should be spent on IVSI especially during level off and steep turns. Session 2 - Again IVSI cross check even more important as progression. Session 5 - More time spent on IVSI (especially when experience was on Non-IVSI Aircraft) would have been helpful.
107	1105	CP	Session 1 - Transition from Instruments to visual landing. Session 3 - Holding; stalls. Session 5 - Go around procedures.
108	1106	CP	Session 3 - Yes. The heavyweight take off with V1 cut on Rwy 23 at Roanoke where a turn is required immediately after. I needed to concentrate more closely on the

ATTACHMENT II (continued)

IP	Trainee	Status	Trainee Comments
			ADI for proper pitch and bank control in starting that turn.
107	1107	CP	Session 2 - Transition from instruments to visual on Precision approaches. Session 5 - NDB Approach. Scan seemed to break down at the ADF instrument.
108	1108	CP	Session 1 - Yes. Trouble with the ILS using the flight director. Session 3 - Yes, during all maneuvers. I have been acting as a flight engineer for the last year and my scan is low. Session 4 - All instrument approaches Scan is improving slowly but I do feel that if it could be monitored it would improve faster. Session 5 - Today was the check ride and it went well but I feel that one more day is needed to be fully up to speed. Some type of scanning procedure might have helped eliminate the feeling that another day was needed
106	1109	CP	Session 1 - Steep turns; stalls. Session 2 - Steep turns; stalls. Session 3 - Steep turns. Session 4 - Stall #3; circling approaches.
104	1110	CP	Session 1 - Rapid depressurization; emergency descent; stalls; steep turns; ILS short final. For first session, not always sure where to initially check. Session 2 - NDB approach, normal ILS; stalls. Concentration on finding power settings led to more airspeed deviations resulting in higher power charges than necessary Session 3 - Circling approaches (single or two engine); emergency patterns (jammed stabilizer and

IP	Trainee	Status	Trainee Comments
			single engine). Cross check becomes considerably slower if compounded with emergency patterns.
			Session 4 - Manual reversion; small #3; circling approaches.
103	1201	P	Session 1 - I found myself fixing on F.D. I finally forced myself on scanning pattern.
104	1202	P	Session 1 - Power adjustments.
104	1203	P	Session 1 - Yes. Setting up radios and fly aircraft at same time. V1 cuts. Session 2 - Aborted T.O. Session 3 - Aborted T.O. Session 4 - ADF approaches. Session 5 - Emergency descent.
106	1205	P	Session 2 - Circle approach. Session 3 - Circle approach.
106	1206	P	Session 2 - Stalls. Session 4 - APP ILLS and VOR.
102	1207	P	Session 1 - V1 cut. Tendency to monitor ADI too much. Needed to monitor VSI more. Session 2 - V1 cut - stall series. Scan is increasing but need to monitor the VSI more closely - also need to get better feel of power levers to the settings. Session 3 - No flap landing. Found self concentrating on one instrument to much. Session 4 - V1 cut as usual - over-rotated - must use VIS better. Scan today was slower than yesterday. Session 5 - VOR, ARC, DME - didn't orient self properly. Scanned better.
102	1208	P	Session 1 - On all maneuvers, not paying enough attention on the IVSI and too much on the ADI.

ATTACHMENT II (concluded)

IP	Trainee	Status	Trainee Comments
			Session 2 - All. Seems to be over controlling: not enough scanning.
			Session 3 - Too much attention on altitude hold and flight director. Not watching IVSI.
			Session 4 - Bad night. Scan very slow.
			Session 5 - Still slow on the scan.
107	1209	P	Session 1 - No. I was too busy with trying to get the feel of the simulator to concentrate on a good instrument scan.
103	1211	P	Session 1 - Steep turns; ILS approaches; VOR approach.
			Session 3 - V1 Cut.

ATTACHMENT III

IPs' Comments on Trainee Rating Forms (Experimental Group)

Q. Did you use the oculometer system to provide feedback to the trainee? ____yes ____no. Please explain.

IP	Trainee	Status	IPs' Comments
102	2101	CP	Session 1 - I believe this will be valuable at a later date. Session 2 - Pointed out that scan slow Did not use raw data enough. Session 3 - Need another day of training. Session 4 - After viewing tape trainee's scan improved approximately 40% over previous period. Session 5 - The system has been helpful for all five periods.
102	2102	CP	Session 1 - System INOP Session 2 - Pointed out that he need to cross check raw data more. Session 3 - Trainee improved approximately 50% after viewing tapes of previous day. Session 4 - It was helpful. Session 5 - Trainee made a 50% improvement after viewing tape after second session.
109	2201	P	Session 1 - Helped to smooth out his flying. Caused to incorporate IVSI into scan, so as to make smaller pitch corrections to correct altitude losses or gains. Session 2 - Stabilize sink rate of 1,000' per minute on non-precision. Session 3 - Improve altitude and airspeed hold during a circling approach. Session 5 - Used it for steep turns and go arounds with an engine out. In the engine out, told student to scan IVSI to maintain a positive rate of climb.
109	2202	P	Session 1 - Helped to incorporate the IVSI more into his flow. Helped to smooth out pitch charges on aircraft.

ATTACHMENT III (continued)

IP	Trainee	Status	IPs' Comments
			Session 2 - Scan to stabilize on 1,000' per minute rate of descent on a non-precision approach.
109	2202	P	Session 3 - Used it less than prior two sessions, because we incorporated a better flow pattern due to the oculometer, for the third session.
107	2203	P	Session 1 - Student has no problem that could be attributed to poor scan. Can see potential especially with problem student.
			Session 2 - Traditional training methods prevailed. Did notice an increase in scan pattern.
			Session 3 - Did not seem pertinent this session.
			Session 4 - Scan was very complete. Very good session.
			Session 5 - Student had no problems that could be attributed to scan.
110	2205	P	Session 1 - On steep turns there was a tendency for the trainee to concentrate too much on helping instead of alt., airspeed and altitude.
			Session 2 - Found monitor to be helpful as it showed the student was spending too much time during approach looking at approach plate and letting altitude and airspeed go.
			Session 5 - Extremely busy preparing student for checkride and 90% of session was devoted to procedures.
111	2206	P	Session 2 - Very impressed.
			Session 3 - Very helpful.
			Session 5 - Very helpful.
111	2207	P	Session 2 - Very impressed.
			Session 3 - Helpful.
			Session 5 - Very helpful.

ATTACHMENT III (concluded)

IP	Trainee	Status	IPs' Comments
112	2208	P	Session 1 - Able to discuss scan patterns and discuss fixation on one particular instrument.
113	2209	P	Session 1 - Adjusted scan for stalls and steep turns.
114	2210	P	Session 1 - Adjusted scan for stalls and steep turns
115	2211	P	Session 1 - Too much attention on IVSI on stalls and steep turns.

ATTACHMENT IV

Trainees' Comments on Self-Rating Forms (Experimental Group)

Q. If you were exposed to video tapes of your instrument scanning, did you find the information useful? Please explain.

IP	Trainee	Status	Trainee Comments
102	2101	CP	Session 2 - Helped show that I am not looking at the IVSI.
102	2012	CP	Session 5 - Excellent training aid.
107	2203	P	Session 5 - Hard to analyze video replay.
111	2206	P	Session 1 - Reinforced training procedures.
111	2207	P	Session 1 - I viewed a portion of the tape of the other trainee and found it very interesting.
116	2212	P	Session 5 - I have not reviewed my video-tapes at this time although I intend to do so in the next future. Good program! It proves to be very helpful at times.

ATTACHMENT V

Trainees' Comments on Video Tape Usage Forms
(Experimental Group Only)

Trainee	Status	Training Session	Maneuvers Watched	Comments
2101	CP	2	Steep turns; stalls;	Help showed where I was not watching the IVSI.
		4	Steep turns; stalls; manual reversion; single eng a system.	
2102	CP	2	Steep turns; stalls; ILS missed.	Very helfpul information. Excellent information
2201	P	1	Steep turns; stalls; single engine approach.	----
		2	Steep turns; NDB missed.	----
		3	Steep turns; stalls; single engine VOR	----
		4	Zero flap missed.	I feel that his program has been worth at least one day's training.
2202	P	1	V1 Cuts	----
		2	Steep turns; stalls; single engine approaches	
		3	NDB miss, VOR miss; V1 Cuts	----
		4	Steep turns	----
2203	P	2	NDB approach; split flap landing.	Very difficult to follow what flight maneuvers are being performed and how to follow the eye scan to improve problem areas.
2206	P	1	V1 cut; SE approach; stalls.	----
2210	P	1	Steep turns; stalls; V1 cut; CAT II APP	On my steep turns it indicated that I was almost ignoring the IVSI.

ATTACHMENT VI

IP's Comments Using the Final Evaluation Form
(Experimental Group Only)

IP	Status of Trainee	No. of Times Video-Tape was Reviewed with the Trainees	Maneuvers Most Helped by Oculometer System	Comments
102	CP	3	---	It seems to be very helpful for first officer training
110	CP	0	Stalls and approaches	--
110	CP	0	Stalls	Although I did not use the oculometer very much I feel it can be very useful in certain situations.
103	P	0	Steep turns; stalls, non-precision approaches, and V1 cut	I need to review the scans with the students during the video replay next time to give you an answer. Off hand I don't believe the videos would be very helpful.
107	P	0	Instrument Approaches	I feel the oculometer will be very helpful with the problem student (i.e. engineer that hasn't flown lately or a student with low instrument time). This student already has developed a good pattern and habits and did not need any coaching in basic.
111	P	1	All Aspects	I think this could be very helpful in our program. Very helpful! With Experience.

ATTACHMENT VII

Trainees' Comments Using Final Evaluation Form

(Experimental Group Only)

Trainee	No of Times Video Tapes were Viewed	Maneuvers Most Helped by Oculometer System	Comments
2101	3	Most instrument maneuvers.	Very helpful.
2102	3	All instrument work.	---
2201	5	Steep turns ILS missed approaches.	As I stated earlier, I feel the oculometer project helped by no less than one days training.
2202	4	Very helpful in improving scan.	I believe this videotape program is very helpful. I feel it has improved my scan 100%.
2203	1	During emergencies when one is being distracted from flying.	To benefit from the tapes - one needs to have someone to instruct them for a session on the tapes.
2205	0	V1-cuts; ADF approaches.	----
2206	1	Basic instrument manuevers	A good program. I wish that I had more time to view the tapes.
2207	1	Any precision approaches or any instrument work	I spent my time preparing for the evaluation and really didn't have time to view my tapes.
2208	0	Steep turns	

Comments by trainee 2204: After completing the Captain upgrade course, I feel that I can now objectively comment on the oculometer program that I participated in for five days.

When I viewed the 1st session tape, I immediately noticed that my scan was very limited. The tape also helped me to realize that I was spending little, if no time on engine instrument scan, i.e., fuel flow, oil pressure, N_1 Σ N_2. This was very evident on takeoff rolls and right at engine V1 speed.

In my opinion the oculometer program helped me more than anyother device in improving my scan pattern.

As a flight instructor, it is my opinion that a system like this would be very helpful in student training, pilot upgrading and recurrent work. As I viewed each session I was able to strengthen my scan pattern by constanly viewing instruments that I knew I was spending little or no time on at all.

I highly recommend the use of this excellent tool.

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15. Supplementary Notes

Langley Technical Monitor: Amos A. Spady, Jr.
Final Report

16. Abstract

A study was conducted to determine the effectiveness of incorporating a real-time oculometer system into a Boeing 737 commercial flight training program. The study combined a specialized oculometer system with sophisticated video equipment that would allow instructor pilots (IPs) to monitor pilot and copilot trainees' instrument scan behavior in real-time, and provide each trainee with video tapes of his/her instrument scanning behavior for each training session. The IPs' performance ratings and trainees' self-ratings were compared to the performance ratings by IPs and trainees in a control group. The results indicate no difference in IP ratings or trainees' self-ratings for the control and experimental groups. The results indicated that the major beneficial role of a real-time oculometer system for pilots and copilots having a significant amount of flight experience would be for problem solving or refinement of instrument scanning behavior rather than a general instructional scheme. It is suggested that this line of research be continued with the incorporation of objective data (e.g., state of the aircraft data), measures of cost effectiveness and with trainees having less flight experience.

In addition this research sought to find evidence of performance decrements by pilot trainees on or around the third day of flight simulator training. The data indicate that trainees performing second within a session show performance decrements on the fourth day of training. Results are discussed in terms of fatigue effects.

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